THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. V.

The Upper Valley and the Stream System.

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(Six Text-figures.)

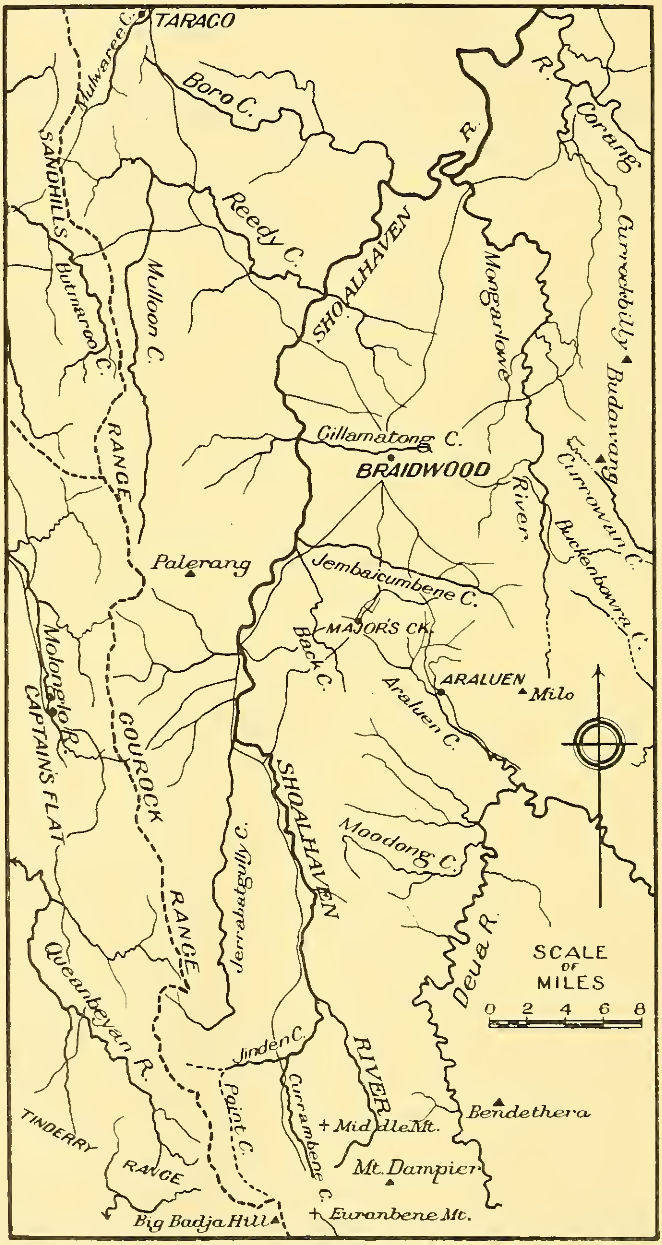
[Read 27th July, 1932.]

The upper valley of the Shoalhaven has not been trenched by modern canyons, but the Shoalhaven Plain extends southward between high ridges to split up into a number of parallel mature valleys as the head of the river is approached. These are separated from one another by hills and ridges which rise to a common level surmounted by the residuals of Gourock Range. The coastal slopes have been dissected by vigorous streams, but on the western side of Gourock Range the meridional valleys of the Murrumbidgee system bear a strong resemblance to that of the Shoalhaven, and the latter gives a key to much of the physiography of the Southern Tableland. In this account the magnetic meridian is used (declination 9° 30′ E.), and the term "coastal slopes" is used to designate the seaward fall to the east of the meridional course of the Shoalhaven River.

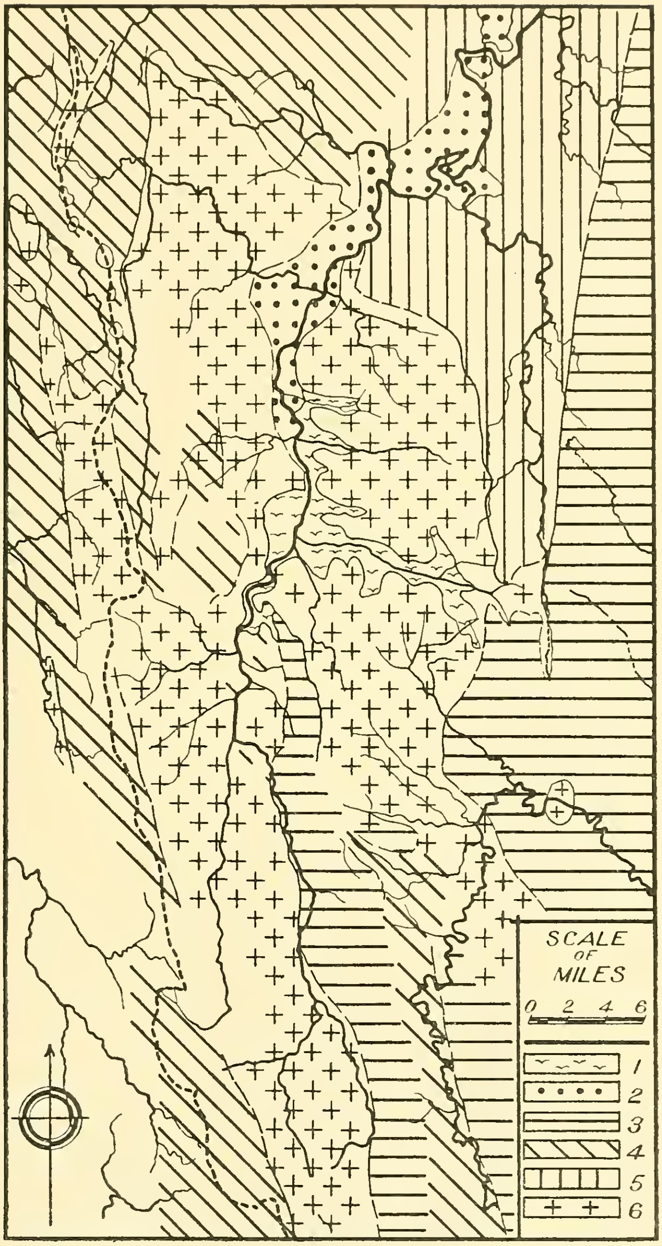
Geology and Surface Features.

The core of the area is a granitic intrusion which extends from the Braidwood district to the head of the river. In general it gives negative topographic features, gentle undulations and well marked terraces, although occasional residuals rise above the level of the surrounding plains. Part of this intrusion has been used in the formation of Araluen Valley which is deep, flat-bottomed, and partly enclosed by higher lands of sedimentary rocks. Porphyries are found along the western margin of the granites, but their principal development is to the west of the Shoalhaven, where they extend in an almost unbroken line from Tarago to the head of the river at Middle Mountain, along the eastern borders of Sandhills and Gourock Ranges. Although responsible for rough and broken country where they are being newly attacked, the porphyries show a generally subdued topography which is less mature than that of the neighbouring granites.

Ordovician sandstones and argillites extend into the Braidwood district from the north, and occupy the lower valley of Mongarlowe River. Like the granites, they form negative features with occasional higher ridges, but the upper Devonian sediments to the east rise high above the Shoalhaven Plain; the hard and massive nature of their quartzites gives the residuals of Currockbilly and Budawang, but towards the south these rocks merge into sandstones, and the strike ridge surmounting the coastal slope has been breached by attack from the east. There is also a progressive change in the amount of folding on this part of the Shoalhaven divide, for the steep eastward dips of Currockbilly and Budawang pass southward into the Deua basin, while the more westerly extension of the series at Major's Creek has only been slightly folded (David, 1893), and its continuation to Mt. Dampier is almost horizontal in most places. These rocks belong to the Lambie stage of the upper Devonian, and overlie older folded rocks containing limestones (I. Brown, 1930, 1931).

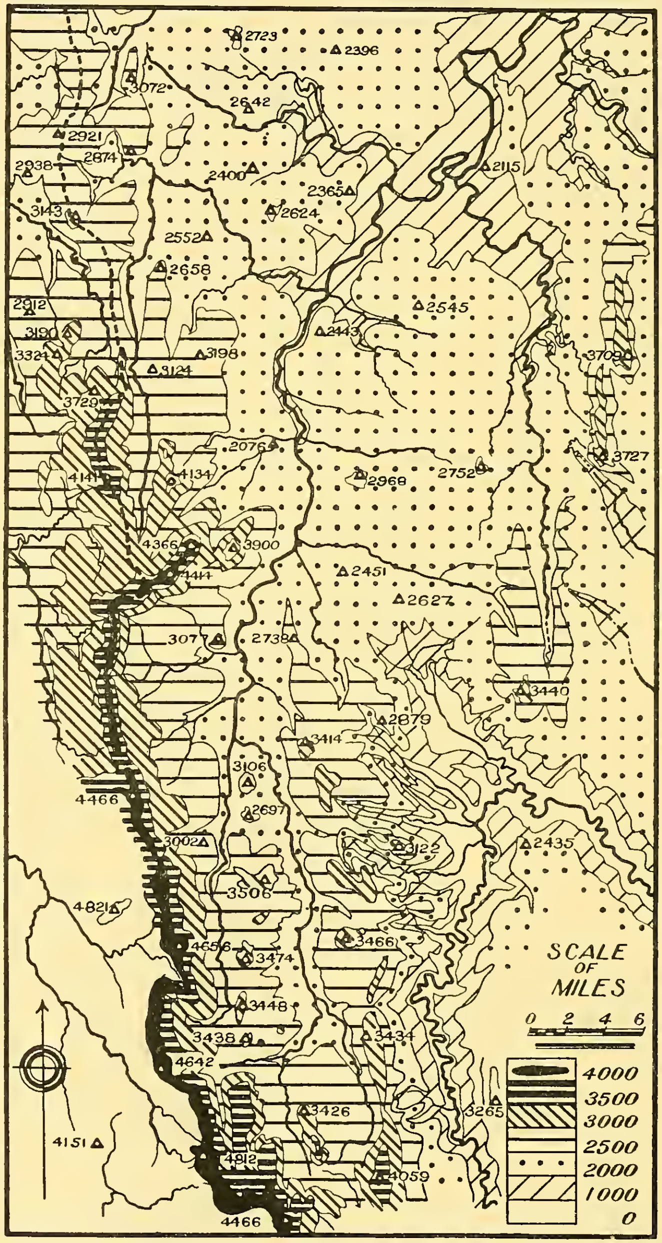


Text-fig. 1.—Locality map of the area. The heavy broken line indicates the position of the Main Divide, which bifurcates to enclose Lake George.



Text-fig. 2.—Geological sketch-map, based on the State Geological Map, 1914, and the work of Dr. Ida A. Brown. The numbers indicate: 1.—Alluvium, Pleistocene and Recent; 2.—Pliocene river drift; 3.—Upper Devonian; 4.—Middle Devonian and Silurian, possibly including older rocks; 5.—Ordovician; 6.—Granites and porphyries.

On the western divide there is a series of sandstones, limestones and slates, which are associated with hard quartzites. They have a general westerly dip on Sandhills Range, and their harder members are responsible for the scarps



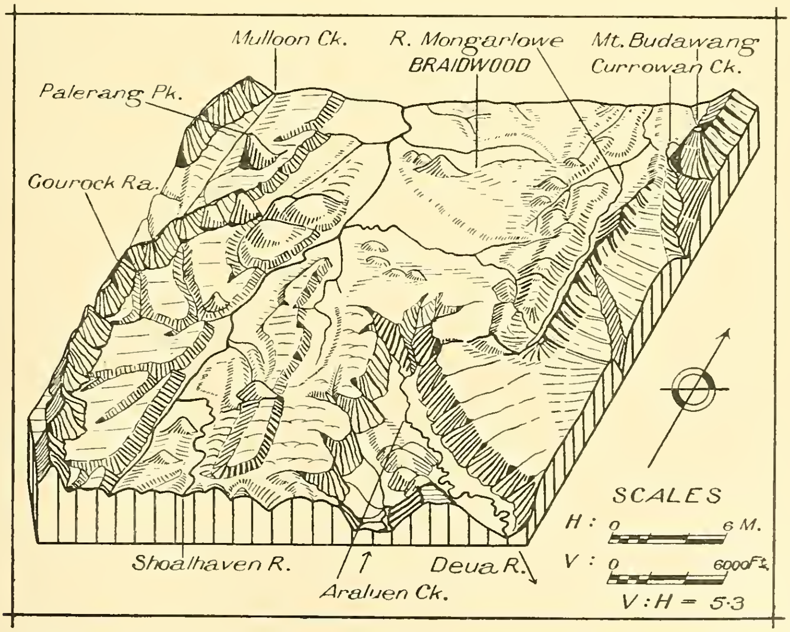
Text-fig. 3.—Orographic sketch-map, based on trig. heights, road traverses and photographs.

found to the west of Mulloon and Mulwaree Creeks. Gourock Range is capped with sedimentary rocks and massive quartzites which appear to have been lifted up by the granitic intrusions, as they occur at much higher levels than the sub-horizontal rocks on the eastern divide of the Shoalhaven, and they dip steeply westward: this is the oldest part of the existing highlands.

On the whole, we find that rock character and structure have had an effect on scenery similar to that in other parts of the Shoalhaven Valley, but as the head of the river is approached the higher levels between 3,400 and 4,000 feet are found to comprise a great variety of rocks—horizontal sandstones, porphyries, granites, and folded sedimentary and metamorphic rocks—which have been reduced to a common level in times past, giving a surface as complex as the Shoalhaven Plain: it will be referred to as the "older peneplain".

Topography and Physiography.

The Eastern Divide.—Passing southward from the head of Corang River, the horizontal Permian sandstones at 2,800 feet give place to broken hills of Devonian quartzite at a similar level, and then to a long ridge which rises from beneath the sandstones and continues their upper surface southward to Currockbilly Trig. (3,709 feet). The scarp faces westward and rises abruptly from the Shoalhaven Plain, while erosion on the coastal side has combined with a steep dip to give broken slopes and precipices. Beyond Currockbilly the ridge is lower and serrated, but it rises again to Budawang Trig. (3,727 feet), whence it falls to the gorge of Currowan Creek, which has cut across the eastern wall of Mongarlowe Valley and is extending into the Shoalhaven Plain. The lowest part of the divide between Currowan Creek and the Mongarlowe is on a broad



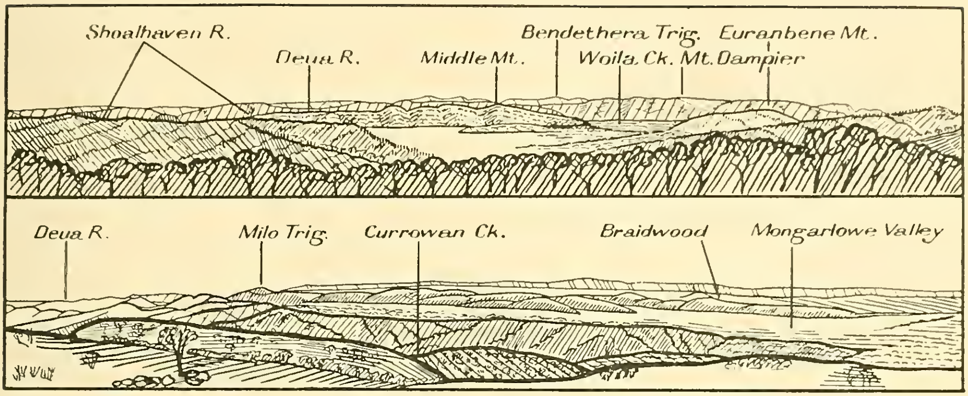
Text-fig. 4.—Block diagram of the country towards the upper Shoalhaven, to show the various surfaces of erosion and stream attack on the tableland.

plain about 2,210 feet, which compares with the high-level drift terraces at 2,200 feet found along the Mongarlowe immediately to the west. It thus appears that Currowan Creek attacked from the south-east along a line of weakness, and captured a small portion of the upland drainage area.

Still continuing southward there is a general rise on either side of the Mongarlowe, but swift tributaries of the Clyde fall down the steep beginning of the coastal slope and have pushed back the divide in places, giving it a serrated appearance. These conditions persist to the head of the Mongarlowe, where there is a depression in the divide about 2,600 feet between the level valley of that stream and the gullies falling to Deua River. But there is a much greater gap in the decomposed granites at the head of Araluen Creek with points as low as 2,300 feet: one of these low places is at the village of Major's Creek, where a small stream of that name falls rapidly to Araluen Creek and is cutting back into its divide, which lies on the edge of a wide plain at 2,300 feet falling gently to Back Creek and the Shoalhaven; the river is rather less than four miles to the north-west, and is flowing at 2,150 feet. This part of the Shoalhaven Valley has the appearance of being perched insecurely above the coastal gorges, and a similar position exists further to the east where small streams flow north-westwards across the Milo scarp: the largest falls to Jembaicumbene Creek, but the others change their direction and pass into gullies which lead steeply to Araluen Creek. That stream has been favoured in its attack on the tableland by its steep grade, by lines of weakness in the rocks, and by the readiness with which the granites decompose. It has enlarged itself at the expense of the Shoalhaven drainage, and is even threatening the upper Shoalhaven with capture.

Other gaps of a similar nature but of less consequence are found at intervals along the Shoalhaven-Deua divide. Perhaps the most impressive is opposite the horseshoe bend of Moodong Creek, which falls steeply to the Deua and appears to have encroached on the Shoalhaven drainage. The lowest point on this part of the divide is at 2,500 feet—200 feet above the level of the Shoalhaven and 2,000 feet above the more distant Deua—and the divide itself crosses a gentle plain which falls abruptly to Moodong Creek. In the less broken parts of the eastern divide high points rise above 3,400 feet and the crest line is little lower (Text-fig. 5); there is a rise southwards to Mt. Dampier at 4,060 feet, whence there is a gentle fall for some distance towards the Tuross, and then a steep plunge to its gorge.

Going from Mt. Dampier to the head of the river we find the Shoalhaven and Currambene Creek rising in level swamps between 2,800 and 2,900 feet on opposite sides of Middle Mountain (3,750 feet), and flowing northward through wide, gentle valleys. The plain continues on the southern side of the mountain, and parts of the Shoalhaven swamps drain southward into a steep-sided trench from 30 to 50 feet deep which has been cut in the earth plain by a wavering stream. At first this creek flows east-south-east, but it soon turns southward to fall into a steep-sided gully, and thence to the deep gorges of Woila Creek and Tuross River. Thus the divide has been virtually eliminated at this place, although a thick mantle of vegetation protects the surface from erosion; the trees and ferns are sufficient to prevent rapid enlargement of the earth trench whilst grass and swamp plants bind the plain, so the present position is essentially one of neutral equilibrium with Woila Creek gaining slightly. The remainder of the southern divide is high with an abrupt fall towards Tuross River and southward

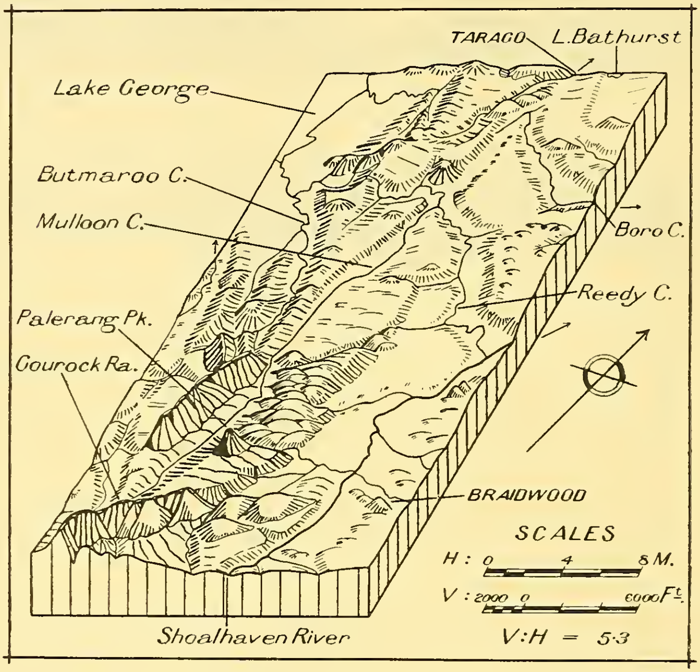


Text-fig. 5.—Topographic sketches from photographs, showing: I. A view from the heights two miles north of Big Badja Hill to illustrate the skyline of the older peneplain and its gentle northward fall. The streams on either side of Middle Mountain flow to the left, but Woila Creek passes on the far side of Euranbene Mountain through the breached divide and falls to Tuross River. II. A view from Budawang Trig. The gorge of Currowan Creek passes to the left across the eastern ridge of Mongarlowe Valley to the dissected coastal slopes. The ocean is in the left background.

from Big Badja Hill along the Main Divide: towards the north, Point Creek flows through a gorge cut in metamorphic rocks to emerge on a granitic plain above its junction with Jinden Creek, and its eastern divide shows a normal fall northward from 4,400 to 3,600 feet.

Summing up, we find that active erosion from the east and south has breached the divides of the Shoalhaven and, favoured by steep grades, lines of weakness and the stability of the Shoalhaven Plain at a high level, tributaries of the Clyde, Deua and Tuross are beginning to encroach on the Shoalhaven drainage. A definite progression of events is shown: in some cases the divide is being irregularly lowered; in others it has been breached and gorges are developing in the upland; at the head of the river diversion of drainage is actually taking place, although its ultimate result cannot be very spectacular.

The Western Divide.—The southern end of Gourock Range rises sharply from 4,000 feet at the head of Point Creek to 4,800 feet, and a peak some 500 feet higher is found to the north-west on Tinderry Range. The main ridge is level and uniform, with occasional high-level passes about 3,800 feet; its eastern slopes and branches are interesting because they comprise a triangular area of granite terraces between 2,800 and 3,200 feet, an elevation comparable with that of the high points between the Shoalhaven and Jerrabatgully Creek, which rise somewhat above 3,400 feet. The terraces slope towards the river, but isolated hills on their eastern edge rise above 3,000 feet, and indicate that the edges have been smoothed down subsequent to the formation of a level between 3,000 and 3,200 feet. It is possible that horizontal separation planes in the granite made the perfection of these terraces possible, and in any case the sharp westward rise when the sedimentary and metamorphic rocks are met proclaim Gourock to be an ancient feature rising above this erosion level, whose northward continuation is found in the gap to the west of Palerang Peak, the ridgy tableland on either side of that hill, much of the western divide of Mulloon Creek and the extension of that crest plane into the drainage areas of Butmaroo Creek and Molonglo River. Mulloon Creek cuts Gourock in two because it and a tributary of the Molonglo have encountered a granitic zone lying between them, and have reduced the divide at that place.



Text-fig. 6.—Part of the western divide of the Shoalhaven, to show the erosional levels and the development of Boro and Reedy Creeks.

When we come towards Reedy Creek we find the 3,000-foot level in Sandhills Range represented by isolated hills, while a notable terrace develops about 2,600 feet, beginning some 5 miles south of the junction of Mulloon and Reedy Creeks. To the east of these streams the granitic country has been lowered irregularly to 2,400 or 2,500 feet, although occasional points rise higher. The northward continuation of this terrace is one of the features about Tarago and Lake Bathurst where it is perfectly developed in sedimentary rocks at 2,400 feet, although its relative importance decreases in the valley of Mulwaree Creek, where it has been reduced in the formation of Goulburn Plains at 2,000 feet so that only occasional rounded hills survive. It is more important to the north-east of Lake George, although here again it has been limited by later erosion.

A description of the western divide would be incomplete without reference to a lineament which comprises the valleys of Mulloon, upper Boro and Mulwaree Creeks, although discussion of its significance can be taken later. The western side of this feature is a straight scarp between 300 and 400 feet high forming the edge of a high terrace and consisting of sandstone, quartzite and occasional limestones. On account of its general resistance it is little dissected, and such streams as the heads of Reedy and Mulwaree Creeks have cut steep notches in its base, although much wider valleys exist above 2,400 feet, thus giving "valley-in-valley" forms. Erosion is proceeding actively in the lower stage.

Considering the streams involved in the lineament we find that they follow the strike of the rocks; Mulloon Creek is established on the edge of the granites, although the northward continuation of the valley to Tarago does not follow this boundary slavishly, and parts of it are eroded entirely in sedimentary rocks. Thus the valley is bounded by a sharp western scarp and a more undulating and broken rise eastward, and although this side attains an elevation of 2,600 feet, it is cut across by the valleys of Boro and Reedy Creeks, both of which streams fall quickly and occupy rather narrow valleys in a weathered surface. The general impression of continuity is still given by this eastern ridge, and the character of the high terrace has not been materially obscured. So far as the valley floor is concerned, the divide of Mulwaree and Boro Creeks near Tarago is found at 2,340 feet; a wide fall leads to Boro Creek at 2,300 feet, whence there is a southward rise to the Reedy Creek divide at 2,400 feet. In that place the valley is flat-bottomed, a half-mile wide, and has evidence of past volcanic activity in the form of an ironstone knoll on the western edge and a surface covering of limonite and bauxite at 2,550 feet on the hills to the east where the Tarago-Braidwood road crosses them. Still further southward the valley floor falls to Mulloon and Reedy Creeks at 2,270 feet, and for several miles southward the former is level, although its grade is steeper in the higher land, and the stream flows at 2,800 feet to the north-west of Palerang Peak, where its course is again level.

In passing we may note the grade of Reedy Creek, which is fairly uniform between Mulloon Creek and the river and averages 30 feet per mile—a remarkable figure for such a large stream flowing in a valley like that of the Shoalhaven, and one which is not approached in other granitic parts of the same area, even by much smaller streams. Boro Creek forms the one exception to this rule, as the first 13 miles of its course away from the meridional valley fall at the same rate, although the lower 6 miles only average 13 feet per mile. The lower part has been assisted by tributaries, but it lies below 1,900 feet and is the immediate result of channelling in the Shoalhaven Plain. On the other hand, five-eighths of the steep upper fall lies above 2,050 feet, and is thus virtually outside the upper limit of the steepening due to the dissection of that level. If this steeper section developed at the same time as the Shoalhaven Plain its grade is distinctly anomalous, and is not reproduced by more normal tributary streams, such as those of Nerrimunga Creek. Boro Creek has not encountered very resistant formations during its downcutting, so it would appear that the upper part of the steep section has been formed comparatively recently, probably being one of those features which developed during the formation of the Shoalhaven Plain (2.050 foot level) in contradistinction to the streams responsible for that feature, such as Nerrimunga and Barber's Creeks. A similar but less clearly defined state of affairs exists along Reedy Creek.

Reverting to the western divide for a moment, it will be seen that there is a general northward fall of a high-level peneplain surface from the head of the river, with increasing complexity as new levels and terraces make their appearance in the northern margin. Gourock Range has been preserved by sedimentary and metamorphic rocks, and appears to be a survival of a very ancient tectonic feature.

The Shoalhaven Plain.—The upper valleys of the Shoalhaven fall from 2,900 feet at their head to 2,400 feet at the junction of Jinden Creek with the river; beyond this the valley increases in width and maturity, and the divide between the river and Jerrabatgully Creek is greatly reduced in places, the topography being that of a maturely dissected tableland. Further north the river falls gently, and the deposits of silt and drift on modern or little-elevated flood plains attain a width of a mile; as Braidwood is approached the ridges fall to 2,400 feet, with the granite residual of Gillamatong rising to 2,968 feet, only a little short of the high peneplain level. Still further northward the undulations continue to die out, until at the junction of Mongarlowe River the mature valley has expanded into a peneplain standing a little above 2,000 feet (the Shoalhaven Plain), with a gentle rise to the western divide, and a level expanse to the foot of the Currockbilly-Budawang ridge and to the tableland of horizontal sandstone at the head of Corang River. In earlier papers we have studied the development of this surface and its partial dissection to a depth of 400 feet in the pre-canyon stage between Oallen ford and Tallong: this trenching extends upstream along the Shoalhaven to a point immediately west of Braidwood. Where soft or decomposed rocks were encountered, as at the junction of Reedy Creek and upstream on the western bank in that section, a wide, shallow valley was formed, and was later filled with sand and pebble drift rising to 2,100 feet opposite Braidwood. Subsequent erosion has re-developed this feature, and has given extensive terraces between 1,870 and 1,900 feet at the junction of Reedy Creek, and at a higher level immediately above the Tarago-Braidwood road.

Thus we find the Shoalhaven Valley in this area to be a peneplain cut in a higher and older tableland which rises from 800 to 1,200 feet above it. The lower surface is of a composite nature with one set of levels at 2,000 feet and a higher series lying between 2,400 and 2,600 feet, with details that have been determined by rock structure and resistance. The older levels and terraces fall gently northward, and have their greatest height and least physiographic complexity at the head of the river.

The Stream System.

The principal streams of the Shoalhaven system follow the general northward slope, and they are well adjusted to geological structure. It is this structure which is responsible for their long meridional lines, as their expansion to the east or west has been limited by the hard strata encountered. The best developed tributary systems are those of Nerrimunga and Bungonia Creeks, where the hard ridges stand back from the river, and that of the Endrick, which originated in a fairly uniform sandstone tableland. These three tend towards the dendritic pattern, but there are others whose development has been very restricted; Mongarlowe River, Jerrabatgully and Mulloon Creeks are confined to simple trough valleys for long sections of their courses, and receive only short tributaries from their valley walls. In each of these cases hard strike ridges are the limiting factor, and the considerations involved are simple, as most of the streams of the Shoalhaven system existed before the coming of the late Tertiary basalts and drifts, and it is probable that their essential form survived from much earlier times, as the fall of the older peneplain seems to show. But there are specific questions which remain to be considered, especially the breaches in the Shoalhaven divide, the streams flowing south-eastward, and the course of Deua River. Before discussing them we may consider the factors which govern stream change in such a region as this.

Conditions of Stream Change and Capture.—The most recent account of the normal cycle of stream pattern development is that of Glock (1931), and the existence of such a cycle of development has been well established, provided that the streams commence on a new land surface which is structurally uniform. The pattern of greatest efficiency has a dendritic (branching tree) shape, but modifications of the ideal are introduced by varying rock characters and structures. Some of the tributaries of the Shoalhaven are close to the ideal; considering original slopes and fold structures we may regard the northward-tending streams as being normal, and those flowing south-east or south-south-east as having developed later when the original conditions had been considerably modified. For example, it is possible for Mulloon and Mulwaree Creeks and the Shoalhaven River to have originated simultaneously under the conditions of gentle northward slope which we have indicated, but Reedy Creek was not possible until the Shoalhaven had excavated a valley and brought eastward slopes into being. In a similar way it is difficult to imagine a set of conditions under which the Araluen Creek–lower Deua line originated at the same time as the Shoalhaven, Mongarlowe and upper Deua, and it is still harder to reconcile any scheme of this nature with the facts of topography and structure. We are bound to admit that certain of the streams are of more recent origin than the others, and this leads us to consider some of the conditions of stream change and capture.

At the present time, Australian thought on the matter seems to be in a state of flux, but it is possible to lay down conditions which will guide our discussions. If there is no great topographic barrier between them, the question of capture between streams involves two major considerations: one stream must be working at a significantly lower level than the other, with the higher not lowering its course appreciably, and the lower must be able to push back the common divide until the streams meet, when capture will take place. Much of the confusion in local thought is due to the assumption of revolutionary changes following late Tertiary plateau uplifts, and to contradictory ideas relative to the work of streams. Thus Dr. Marks challenges convention by regarding all divides as being essentially fixed regardless of their symmetry, but he states a probable recession of the order of 3 or 4 miles in the vicinity of Toowoomba (Q.), where a low-level stream is attacking a tableland scarp whose crest forms the divide; in the Shoalhaven Valley a similar recession of the head of Araluen Creek would divert the upper 36 miles of the Shoalhaven into the Deua, so the actual limits of action may be of less importance than local circumstances. This is also realized if we consider the conditions at Middle Mountain, where each mile of recession at the expense of the Shoalhaven would add only one mile to the length of the capturing stream.

When speaking of stream attack Marks writes (1930): "The actual head of a stream is only the end of its valley, the terminal valley side, and it must be graded by the same controls as determine the rest of the valley sides." This conception is illustrated in many basalt areas where streams rise in shallow amphitheatres, but it is not of general application. It is a common thing to find the head of a stream rising very little below its divide, even when the "terminal valley side" is steep. Where such a head comes from a zone of weakness—as in the nature of things it generally will—there is a tendency towards valley elongation in that direction as well as some retreat of the crest or head of the slope due to the grading of the valley sides, and this involves the creation of a new salient in the highland. It will be noticed that I am speaking more especially of attack on a tableland whose surface is approximately constant, and whose edge is the actual divide at the head of the stream. Marks also discussed this case, but his argument assumes that the grade of the "terminal valley side" will gradually decrease "as a uniform slope", and to produce an equivalent recession of the divide as the slope is lowered—"a much greater vertical depth of material has to be removed". The assumption is unsound, as the normal curve of erosion is concave upwards, and the grading of valley sides decreases the average curvature while retaining the more elevated part of the curve as the steepest slope. In other words, recession of a divide will be a gradually decreasing quantity as erosion progresses, but until the curvature of the slope of erosion approximates to zero (*i.e.*, until it becomes slight and uniform), the rate of decrease will only be a portion of that estimated by Marks's calculations based on straight line relationships, and the recession of the divide will progress more quickly and over a much greater range than he is inclined to admit. If attack is proceeding actively from both sides and each stream is lowering its course, the divide will be a cusp formed by the intersecting profiles of erosion, and we can agree with Marks that its lateral movement will be slight unless and until one stream is hung up at a relatively high level, when conditions will gradually approach those of a tableland which is being attacked on one side from a lower level. Davis shows the idea clearly in some of his diagrams (1908, p. 23), and admitting all his assumptions we cannot doubt his conclusions in these matters generally, although their reproduction in the field is an altogether different question.

In our own tablelands the number of captures indicated between active streams is small, especially if allowance is made for the configuration of the surface and the great length of time over which the streams have been working, and, although it is possible to infer the destruction of primitive systems over wide areas, and their replacement by the existing patterns, it is difficult to demonstrate cases of individual change involving radical departures from pre-existing conditions: when we have mentioned Mulloon Creek, the Deua and upper Murrumbidgee Rivers we have about exhausted the forms which look like such instances in south-eastern New South Wales, and although it is probable that unsuspected captures have taken place in this region, it is unlikely that first class streams were affected, and even the three instances quoted are comparatively unimportant. This state of affairs may be attributed largely to two things: in the first place, no rock has been sufficiently resistant to withstand the downcutting of a vigorous stream, and in the second zones of weakness are generally parallel to prevailing slopes and primitive stream courses. The first has far-reaching consequences, for except in the cores of the tablelands even the smallest streams that were revived by late Tertiary uplifts have graded their courses by cutting deep gorges almost to their divides, or, in the case of the longer streams, far upstream into the central masses. In this process hard rocks have suffered with the softer formations: thus the Cox and Kowmung Rivers in the Central Tableland have cut across hard quartzites near where these have stood above sea-level as hills since Upper Marine times, and they have continued their grading almost to their divides. An effect of like nature is revealed by Marks's studies in the Brisbane region, where short streams falling directly to the coast and others which take more roundabout courses through harder rocks have both cut down almost to base-level without any notable change in their mutual relationships, although subsequent denudation has widened the short valleys of the direct streams into plains, while those of the more powerful and less direct system in more resistant strata have retained much of their youthful appearance. A similar state of affairs has been noticed in various parts of the Shoalhaven Valley.

With respect to the second point I have mentioned, it is sufficient for the present to remark that eastern Australian conditions are vastly different from those obtaining in places where more complex fold systems and a more striking differentiation of resistances have gone hand in hand. Such conditions are emphasized in Davis's (1909) discussion of western Pennsylvania or Lobeck's (1924) illustrations of part of the Appalachian region with its highly diversified fold systems and related topography, but they hardly exist in this State, where we can regard the pre-Permian stratified rocks (and the Permian also in places) and the granites as having given surfaces of erosion on which parallel lines of weakness are ruled in three families—meridional, transverse, and oblique, the last-named ranging from NW–SE to NNW–SSE (David, 1914; I. A. Brown, 1928), and the younger rocks as giving gently warped surfaces on which streams may have been determined by original slopes, although obviously the matter cannot be discussed here.

To sum up: we agree with Dr. Marks that there has been no great rearrangement of drainage in the region as a consequence of late Tertiary uplifts, but dynamic stream change and capture are realities under rather limited conditions, and they may have played some part in the development of our drainage—a part determined by conditions of structure, slope and elevation.

Effect of Vegetation.—Another factor which exerts a great effect on erosion and stream change is the presence of vegetation, which covers almost the whole of our tablelands and tends to reduce erosion to a minimum even on steep slopes. When this covering is destroyed the soil and rock are attacked and cut away rapidly, especially on the deeply-weathered edges of the newer peneplain. We have noticed one particularly striking example of arrested erosion in the case of the earth gully to the south of Middle Mountain, where the banks are protected by trees, ferns and grass. Such a feature is not formed under present conditions, so we look back to a time in the past when the covering of vegetation was far less effective than it is now, and for conditions under which this would have been possible. Considering the upper valley of the Shoalhaven, we find that snow falls even in the high-level valleys during the winter months, and the climate must have been much more severe during the Pleistocene glaciation, which was estimated by David (1908) as being of the order of 200,000 and 10,000 years ago on Kosciusko, and was unfavourable for the growth of many plants now occurring on the highlands. We also find laterites and yellow earths in the middle valley of the Shoalhaven, and various stream and hill drifts point to conditions of sparse vegetation and storminess with which I hope to deal more elaborately in the near future.

Thus when we compare the present with the immediate past we find that there has probably been a great slowing up in the rate of erosion, which may be lower than it has ever been before under similar climatic conditions, and at the present day the landscape is changing comparatively slowly. This must be kept in mind when the past is being studied, or the present relative equilibrium will lead us to discount ideas of change which are perfectly legitimate on general reasoning. Two specific cases of apparent change may now be reviewed.

Mulloon and Reedy Creeks.—The topography of the drainage area of these streams has already been outlined; Reedy Creek flows from lower into rather higher land, and has a course opposed to that of the Shoalhaven, which it necessarily post-dates. In addition its grade is abnormally steep, and its valley through the higher land is comparatively steep-sided and narrow. On the other hand, Mulloon Creek follows the ancient slope of the land out of the old land masses, and the line of its wide valley continues through the uplands to Tarago, with the high points of the intervening divides showing a falling to the north. The valley does not narrow in those places, and small watercourses within it do not flow appreciably below the inclined planes leading from the divides: it appears that the planes are due to the uniform lowering of an originally horizontal surface. The grade of Mulloon Creek above its junction with Reedy Creek is gentle, and the wider upper members of the valley-in-valley forms on the western scarp rise above the Boro-Reedy Creek divide.

Taking all these facts together and considering the topographic discussion earlier in this paper, it appears that Mulloon Creek originally flowed northward to join Mulwaree Creek near Tarago after passing along a wide valley at a (modern) elevation of 2,400 feet in a gentle plain, with broken ridges of slightly greater altitude to the east. Boro and Reedy Creeks cut back from the Shoalhaven probably when its bed was about 1,800 feet (modern), took advantage of meridional, transverse and oblique lines of weakness which exist both in the granites and in the sedimentary rocks, and broke up the old high-level drainage line, the more southerly stream getting the greater part of the spoil. The most likely time for this to happen, as we have suggested, was after the channelling of the Shoalhaven Plain, but sufficiently long ago to allow a slight lowering of the sections of the captured line and the accumulation of recent gravels about the junction of Mulloon and Reedy Creeks. The implied presence of basalts on the divide between Boro and Reedy Creeks, and on the plains about Lake Bathurst further to the north may have assisted these changes, but on this point we cannot speak with any certainty.

Deua River.—The older peneplain level now above 3,000 feet extended to the east of the upper Deua where the strike ridges of Donovan (2,960 feet) and Bendethera (3,265 feet, Text-fig. 5) form a consistently high level, although the country at the head of the river is lower. This highland is on the same strike as Currockbilly and Budawang ridges (I. Brown, 1930—maps), and owes its preservation to the resistance of its rocks. At one time these sections of ridge to the north and south of the present lower Deua were continuous, and ancient peneplanation reduced the folded strata to the same level as their sub-horizontal and almost unaltered equivalents to the west between Major's Creek and Mt. Dampier. The lower Deua cut across the reduced folds from the then existing coast, taking advantage of the various lines of weakness, and it took part of the original meridional drainage. The effects of peneplanation which gave the Shoalhaven Plain are observed in the wide upland gap across the old Budawang-Donovan ridge, levels above the valley of Araluen Creek at 2,300 or 2,400 feet, and hills rising to a similar height along the Deua above its junction with Araluen Creek, although more recent dissection has destroyed most of the older surfaces in that part. However, the ancient meanders have persisted through the down-cutting, and they show that the present stream line antedates the most recent uplifts, and is at least of late Tertiary age. Oblique lines of weakness in the granites continue to be exploited by the streams between Moodong and Araluen Creeks, and the latter has cut back in a straight line until its head is within four miles of the Shoalhaven with a low divide separating the two. A review of conditions in this section discloses the following circumstances:

1. The older peneplain sloped gently northward, and when conditions favoured the maximum development of the Shoalhaven Plain, it stood 1,000 to 1,200 feet above sea-level (i.e., 700 feet above the subsequently developed plain at Major's Creek + 400 feet of that surface above sea-level, as the plain fell 300 feet to Tallong, which stood rather above sea-level).

2. The main streams flowed northwards over this surface, and the upper Deua may have passed northward to Mongarlowe River. Attack from the east or south-east was vigorous along lines of weakness and the high-level streams, far removed from their active lower courses, remained at a high level for a long period of time (cf. present conditions).

3. The lower Deua cut into the tableland scarp until it captured part of the northward drainage, discovered the granites, and continued to develop tributaries towards the north-west. Base-levelling ultimately reduced much of the country on either side of the Shoalhaven divide to 200 or 400 feet above sea-level, and the divide was breached in various places with the formation of level gaps, but without any appreciable stream change.

4. Further uplift during the latter part of the Tertiary Period elevated the tableland by 2,000 feet: the coastal streams became entrenched and Araluen, Currowan and Woila Creeks continued to invade the tableland. The two former have diverted small streams from the Shoalhaven, and threaten to capture the heads of the Shoalhaven and Mongarlowe respectively, while Woila Creek is encroaching on the swamps at the head of the main stream.

5. A favouring climate and the high development of plant organization has resulted in the whole surface being covered with trees and plants. These have reduced erosion to a minimum, and are holding up stream change and the further development of land forms.

6. With the Shoalhaven cutting back slowly into the tableland through hard rocks and losing the help of its tributaries as recession of the gorges proceeds, it seems that, in the course of time, Araluen Creek may capture the head of the Shoalhaven by way of Back Creek, because it has a steep grade, decomposed rock to deal with, a relatively short distance to travel (four miles), and a divide to deal with only 150 feet above a river which is filling its bed with sand and flowing through alluvial flats.

Summary and Conclusions.

There are two major levels towards the upper Shoalhaven—a high tableland between 3,000 and 4,000 feet with hard residuals and old tectonic features rising to 4,800 feet, and a lower level at 2,400 to 2,600 feet which rises towards the head of the river. It lies 800 to 1,000 feet below the higher surface, and its northward extension has been lowered by erosion to form the lowest or Shoalhaven plain about 2,000 feet which has, in its turn, been channelled to a depth of 400 feet. The trenches thus formed have been filled with drift, and have since been re-developed by erosion both before and after the commencement of the deep modern gorges. Attack is proceeding directly from the coast, and the levels of the Shoalhaven Valley are being invaded by gorges from the east and south. The original streams of the higher surface flowed northward, and their shapes were largely controlled by rock character and structure, but others have developed along parallel oblique lines to modify the original drainage to a limited extent. In addition to these things, the paper discusses the general conditions of stream change and capture, but consideration of the ages of the surfaces involved and of the history of the surrounding country is deferred to a final paper.

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